NASA-CR-72336

GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

ADVANCED REFRACTORY ALLOY CORROSION LOOP PROGRAM

Quarterly Progress Report No. 9
For Quarter Ending July 15, 1967

By

R. W. HARRISON

and

E. E. HOFFMAN

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NAS 3-6474

SPACE POWER AND PROPULSION SECTION

MISSILE AND SPACE DIVISION

GENERAL ELECTRIC

CINCINNATI, OHIO 45215

ADVANCED REFRACTORY ALLOY CORROSION LOOP PROGRAM

QUARTERLY PROGRESS REPORT 9

Covering the Period
April 15, 1967 to July 15, 1967

Edited by

R. W. Harrison

Project Metallurgist

Approved by

E. E. Hoffman

Manager, Corrosion Technology

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Lewis Research Center

Under Contract NAS 3-6474

Technical Management
NASA - Lewis Research Center
Space Power Systems Division
R. L. Davies

SPACE POWER AND PROPULSION SECTION
MISSILE AND SPACE DIVISION
GENERAL ELECTRIC COMPANY
CINCINNATI, OHIO 45215

FOREWORD

The work described herein is sponsored by the National Aeronautics and Space Administration under Contract NAS 3-6474. For this program, Mr. R. L Davies is the NASA Project Manager.

The program is being administered for the General Electric Company by Dr. J. W. Semmel, Jr., and E. E. Hoffman is acting as the Program Manager. J. Holowach, the Project Engineer, is responsible for the loop design, facilities procurement and test operations. R. W. Harrison, the Project Metallurgist, is responsible for the materials procurement, utilization and evaluation aspects of the program. Personnel making major contributions to the program during the current reporting period include:

Alkali Metal Purification and Handling - Dr. R. B. Hand, L. E. Dotson and H. Bradley.

Welding and Joining - W. R. Young and S. R. Thompson.

Refractory Alloy Procurement - R. G. Frank and L. B. Engel, Jr.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

ADVANCED REFRACTORY ALLOY CORROSION LOOP PROGRAM

I. INTRODUCTION

This report covers the period from April 15, 1967 to July 15, 1967. The primary task of this program is to fabricate, operate for 10,000 hours and evaluate a T-111 Rankine System Corrosion Test Loop. Materials for evaluation include the containment alloy, T-111 (Ta-8W-2Hf) and the turbine candidate materials Mo-TZC and Cb-132M which are located in the turbine simulator of the two-phase potassium circuit of the system. The loop design will be similar to the Cb-1Zr Rankine System Corrosion Loop; a two-phase, forced convection, potassium corrosion test loop which has been developed under Contract NAS 3-2547. Lithium will be heated by direct resistance in a primary loop. Heat rejection for condensation in the secondary potassium loop will be accomplished by radiation in a high vacuum environment to the water cooled chamber. The compatibility of the selected materials will be evaluated at conditions representative of space electric power system operating conditions, namely:

a. Boiling temperature, 2050°F

b. Superheat temperature, 2150°F

c. Condensing temperature, 1400°F

d. Subcooling temperature, 1000°F

e. Mass flow rate, 40 lb/hr

f. Boiler exit vapor velocity, 50 ft/sec

g. Average heat flux in plug (0-18 inches), 240,000 BTU/hr ft^2

h. Average heat flux in boiler (0-250 inches), 23,000 BTU/hr ft^2

In addition to the primary program task cited above the program also includes capsule testing to evaluate advanced tantalum alloys of the ASTAR 811 type (Ta-8W-1Hf-1Re) in both potassium and lithium.

Also included in the program is the fabrication, 5000-hour operation and evaluation of a 2600°F, high flow velocity, pumped lithium loop designed to evaluate the compatibility of the ASTAR 811 type alloys, T-111, T-222, and the tungsten alloy, W-25Re-30Mo.

II. SUMMARY

The fabrication of all loop components with the exception of the valves and nine-stage turbine simulator was completed.

The lithium has been distilled and analyzed.

The post test evaluation of the preliminary capsule tests of weld specimens of ASTAR 811 and ASTAR 811CN alloys was completed. The capsule tests have been modified to include the evaluation of ASTAR 811C alloy.

A failure mode effects analysis report for Corrosion Loop I (T-111) is in preparation.

III. PROGRAM STATUS

A. CORROSION LOOP I (T-111) FABRICATION

The fabrication status of T-111 Corrosion Loop components is as follows:

1. Slack Diaphragm Transducer

Taylor Instrument Company returned one of six T-111 transducers when a leak was detected across the diaphragm. This transducer was cut open and the defective diaphragm was removed. Fluorescent penetrant inspection revealed two radial cracks in the diaphragm near the heat affected zone of the weld. Subsequent metallographic examination revealed an intergranular crack in otherwise normal diaphragm material.

The transducer was repaired by welding a new diaphragm in place, and it was subsequently proof tested by applying ten vacuum evacuation cycles on the NaK side of the diaphragm. Mass spectrometer leak testing indicated no failure, and welding and postweld annealing of the assembly was completed. A final mass spectrometer leak test indicated no diaphragm leakage.

The five acceptable transducers were each pulsated five times between vacuum and 0.5 psig by the Taylor Instrument Company. There was no evidence of leakage after testing.

The six transducers will be filled with NaK by the Taylor Instrument Company by the end of July.

2. Lithium and Potassium EM Pump Ducts

The interference fits between the wrapper and EM pump helix were made successfully for both the lithium and potassium EM pumps. The pumps were then processed through the welding and final outside diameter machining phases of their fabrication. The completed EM pump ducts are shown in Figure 1.

The pump ducts were postweld annealed at 2400°F for 1 hour in the General Electric-LMCD vacuum furnace. All conditions were in accordance with Specification SPPS 03-0037-00-A except that pressure was 5×10^{-5} torr at the start of each furnace run and decreased to 1.2×10^{-5} torr during the 1 hour

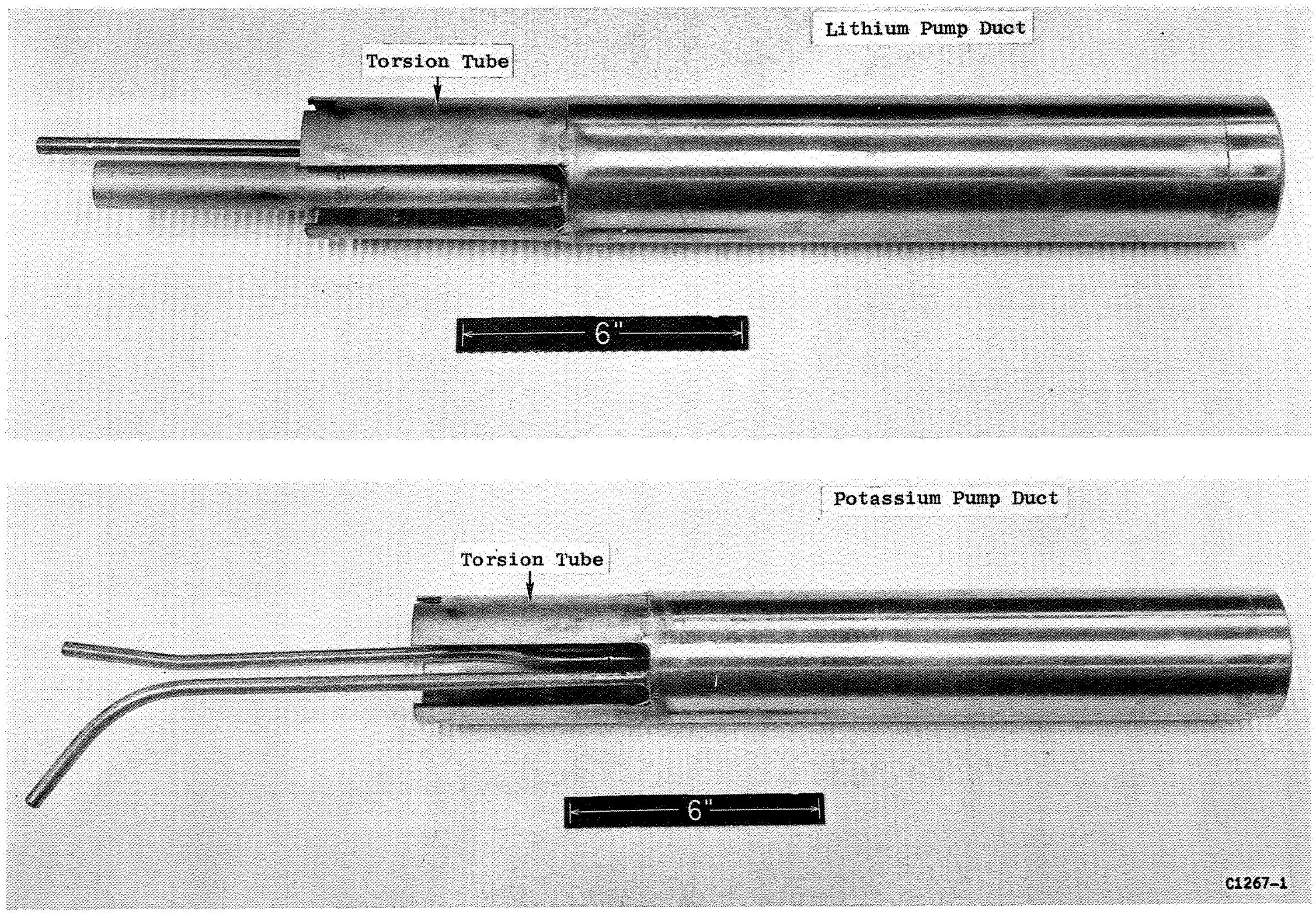

Figure 1. T-111 Alloy EM Pump Ducts for Corrosion Loop I (T-111).
(Orig. C67081421)
(Orig. C67081425)

at temperature. These conditions had been shown to be acceptable by a furnace qualification run performed prior to the postweld anneal of the EM pump duct. Chemical analysis results, shown in Table I, indicate negligible contamination of T-111 alloy sheet specimens placed in the furnace during the qualification run.

3. Throttle and Isolation Valves

The valve body blanks were received from the vendor, Hoke, Inc., Cresskill, New Jersey. The T-111 alloy nipple tubes, 0.375-inch OD x 0.065-inch wall, were then welded to these blanks, and the assemblies were returned to Hoke for final machining. The valve bellows assemblies were also received. Subsequently, the Cb-1Zr bellows were electron beam welded into the T-111 alloy assemblies. Completion of the valves is pending receipt of the final machined valve bodies and valve plugs from Hoke.

4. Turbine Simulator

The ten nozzles were final machined. Results of the inspection of the nozzle diameters are shown in Table II. These dimensions will be used for reference during post test evaluation along with the spare nozzles, part 5 S/N1 (Mo-TZC) and part 6 S/N1 (Cb-132M alloy).

The nozzle assemblies consist of a nozzle, blade, and two pads which support the blade. The single stage turbine simulator nozzle assembly is shown in Figure 2. The nine remaining nozzle assemblies are currently having the blade assemblies fitted into the nozzles. The nozzle, blade, and blade pads of each of the nozzle stages shall be weighed following final cleaning prior to assembly of the turbine simulator.

5. Condenser

The honing of the inside diameter of the two 30-inch long condenser bars was completed. The welding of the condenser was then completed with the joining of the two condenser bars and tantalum fins as shown in Figure 3. This component is now ready for assembly with the nine stage turbine simulator and sub-cooler reservoir to form the condenser major assembly.

TABLE I. RESULTS OF CHEMICAL ANALYSES OF T-111 SHEET FOR HEAT TREATMENT QUALIFICATION OF GE-LMCD VACUUM FURNACE

	PRESSURE, TORR		ELEMENT, ppm[a]			
	START OF RUN	END OF RUN	O	N	H	C
Pre-Test Analysis (MCN 02B-010)[b]			65	5	1	10
Analysis after one hour at 2460°F in the vacuum furnace	2.8×10^{-5}	2.2×10^{-5}				
Wrapped Specimen[c]			63,61	7,7	1,1	3,4
Unwrapped Specimen			68,85	8,8	2,2	7,9

[a] Analytical Procedures: O, N, and H; Vacuum Fusion
C; Combustion Conductometric

[b] 0.040-inch thick sheet

[c] One specimen wrapped with one overlapped layer of 0.002-inch thick Cb-1Zr foil

TABLE II. RESULTS OF INSPECTION OF NOZZLE HOLE DIAMETERS[a]

PART NO.	NOZZLE DIAMETERS PER DRAWING INCHES		ACTUAL DIAMETERS[b] INCHES 0°	90°
1	.0885	.0895	.089200	.089150
2	.0875	.0885	.088075	.087775
3	.0965	.0975	.096380	.096380
4	.1065	.1075	.108350	.108200
5 S/N1	.1175	.1185	.116940	.116475
5 S/N2	.1175	.1185	.118050	.118070
6 S/N1	.1295	.1305	.129975	.129925
6 S/N2	.1295	.1305	.129225	.129225
7	.1445	.1455	.145725	.145750
8	.1595	.1605	.159850	.159825
9	.1775	.1785	.178325	.178525
10	.1985	.1995	.198625	.198660

[a] Measurements made by the Automation and Measurement Division of Bendix, Dayton, Ohio, by means of an electronic comparator using a frictionless electronic transducer compared to master gauge blocks.

[b] The accuracy of the measurement(s) is ±.0001

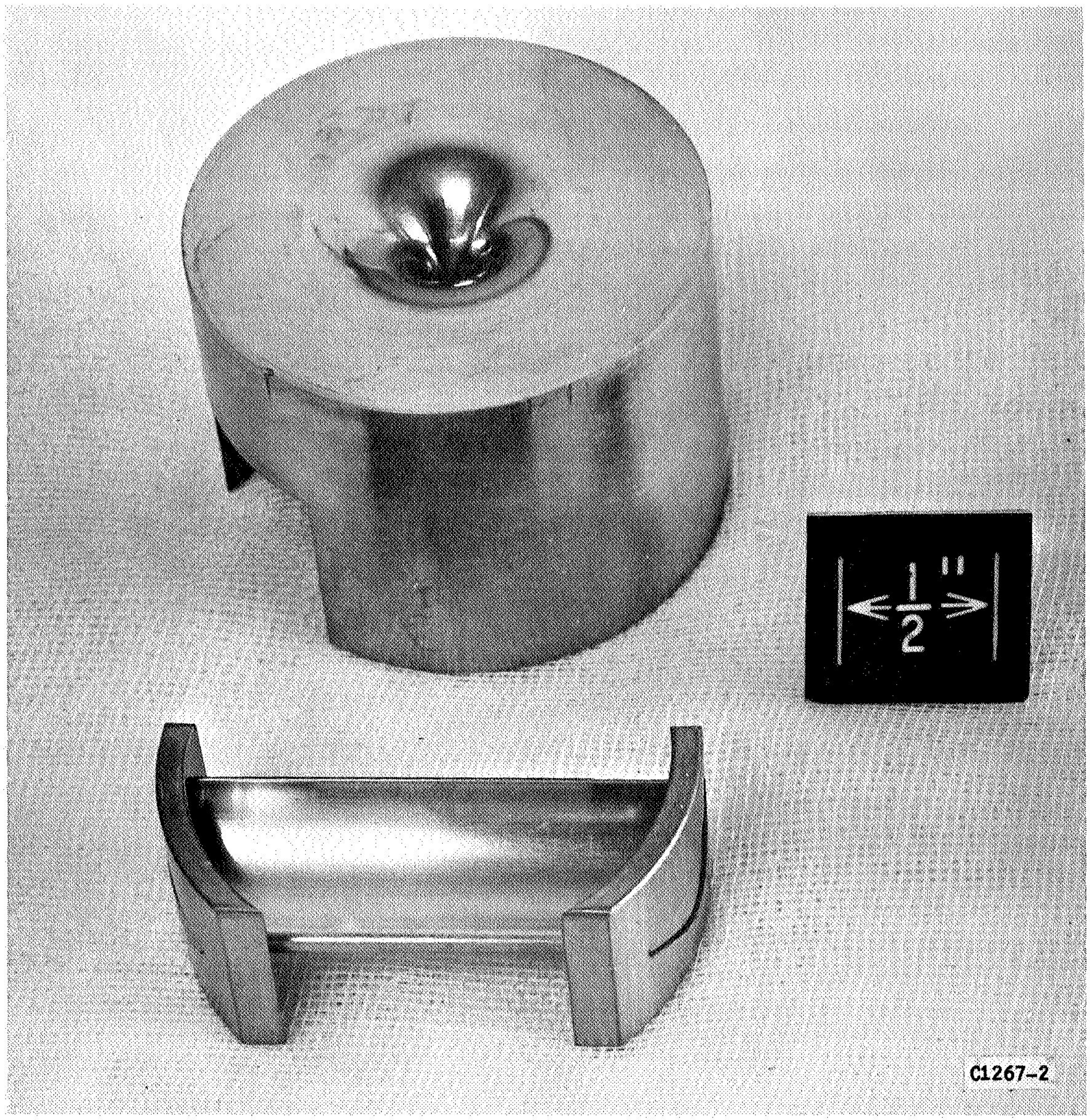

Figure 2. First Stage Nozzle and Blade Assembly (Mo-TZC) for the Turbine Simulator of Corrosion Loop I (T-111). (Orig. C67072546)

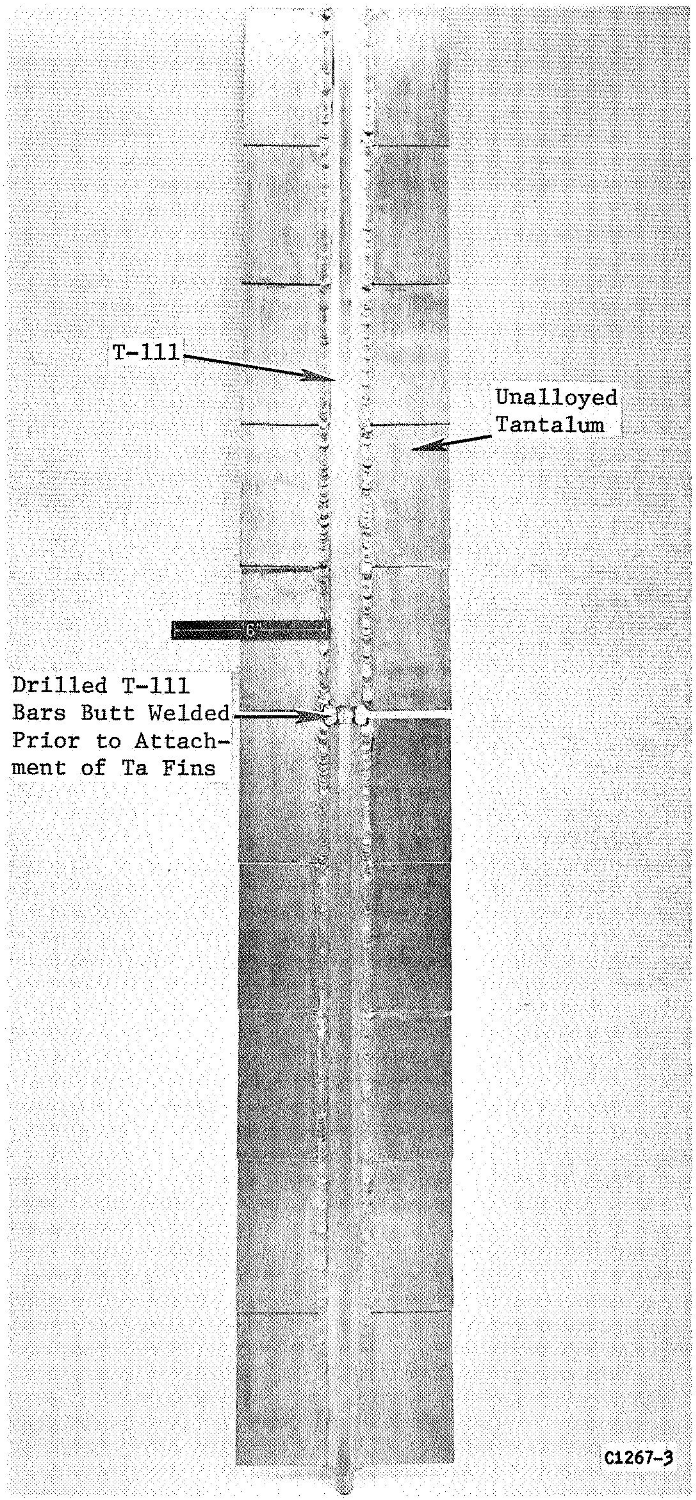

Figure 3. Corrosion Loop I (T-111) Condenser Prior to Coating of Tantalum Fins With Iron Titanate.

(Orig. C67081423)

6. Boiler

The tube-in-tube boiler was formed successfully. The sugar which was used to pack the internal tube and annulus during forming was removed by mechanical vibration. When no additional sugar could be removed, a deionized water flush was initiated. The water was heated to 150°F and was allowed to flush through the boiler for 15 hours. An additional cold water flush for 30 minutes was used for the final rinse. At this time water samples were equilibrated for two hours in the boiler and tested for sugar using the Molisch[(1)] test. Duplicate test determinations indicated less than 50 ppm sugar, which is the limit of detection of the method used.

The final welding of the boiler inlet and outlet connectors was then completed. The assembled boiler and helical plug insert are shown in Figure 4. This component will be incorporated into the boiler assembly, which includes the potassium preheater and single stage turbine simulator, during the next report period.

7. Potassium Preheater and Lithium Heater

The potassium preheater and lithium heater were completed during the last quarter. The lithium heater assembly, Figure 5, will be postweld annealed along with the boiler and condenser assemblies. The potassium preheater, which is shown in Figure 6, will be welded to the boiler during the next report period.

B. ALKALI METAL PURIFICATION

Fifteen pounds of lithium (in three 5-pound lots) were distilled at an average temperature of 1235°F, at the rate of 115 gms/hr. The first two 5-pound batches of distilled lithium were returned to the hot trap to dilute

---

[(1)] Cheronis, N. D., "Techniques of Organic Chemistry", Interscience Publishers, Inc., New York, New York, 1954, p 466-467.

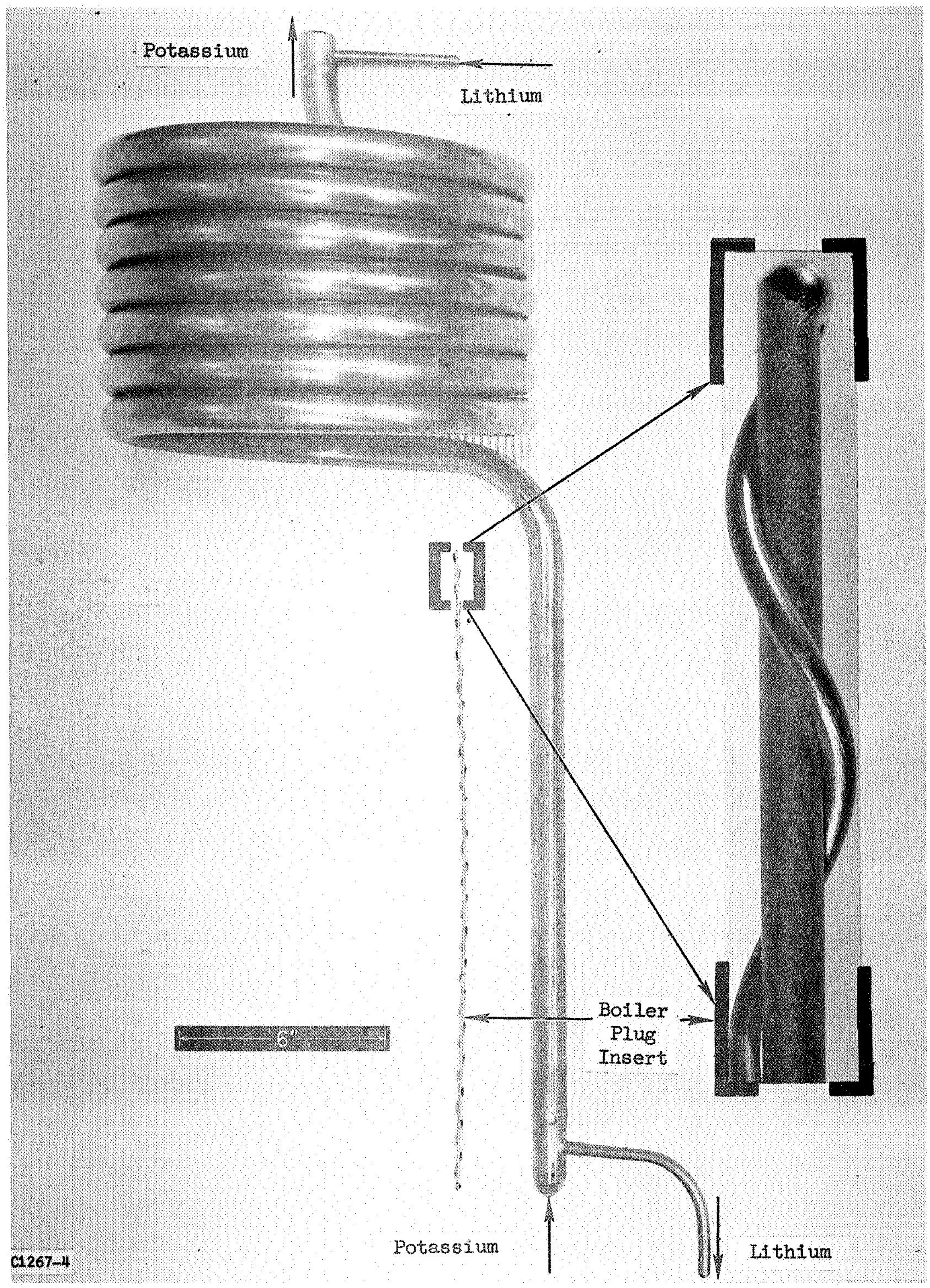

Figure 4. Tube-in-Tube Boiler of Corrosion Loop I (T-111) Prior to Insertion of the Boiler Plug.

(Orig. C67071832)
(Orig. C67072436)

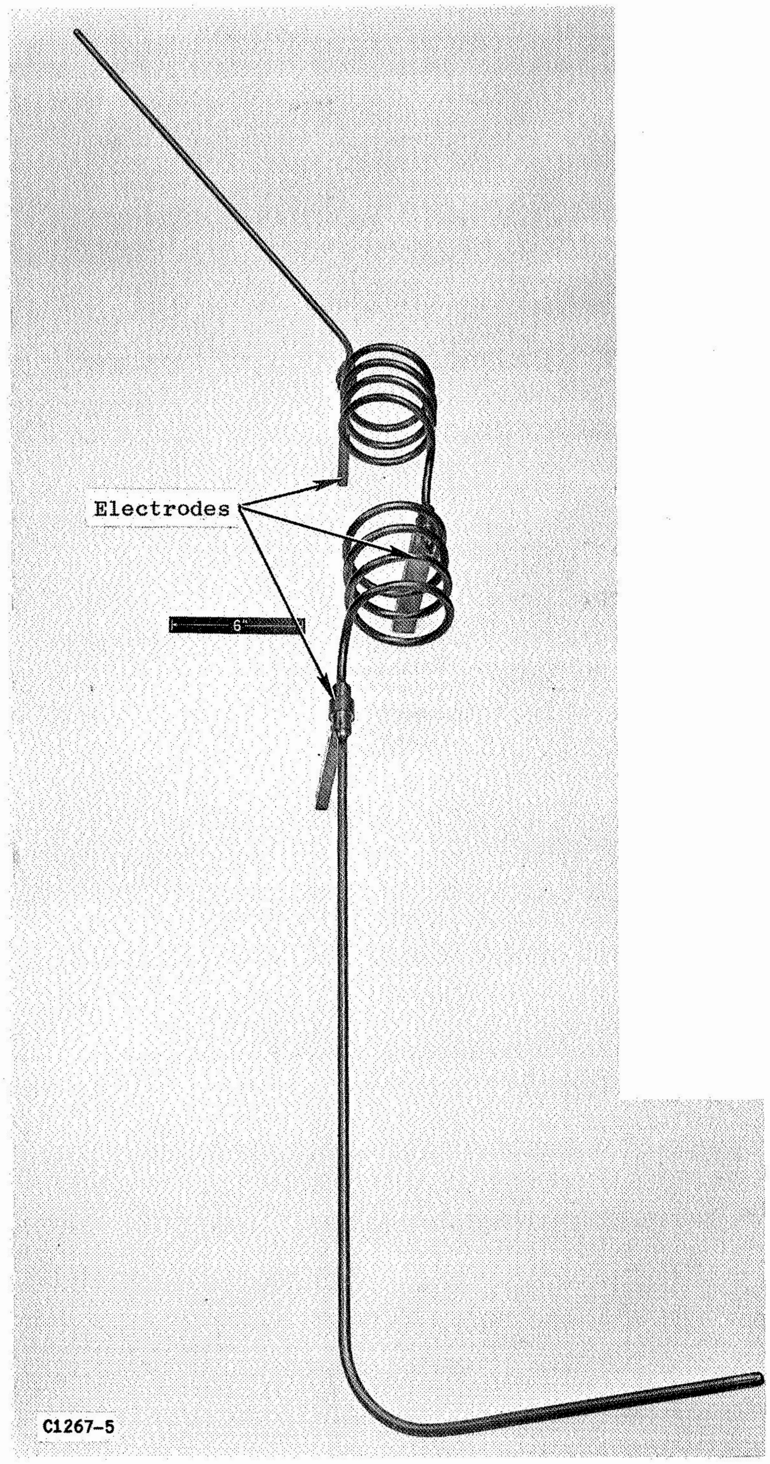

Figure 5. Lithium Heater Assembly of Corrosion Loop I (T-111).
(Orig. C67071830)

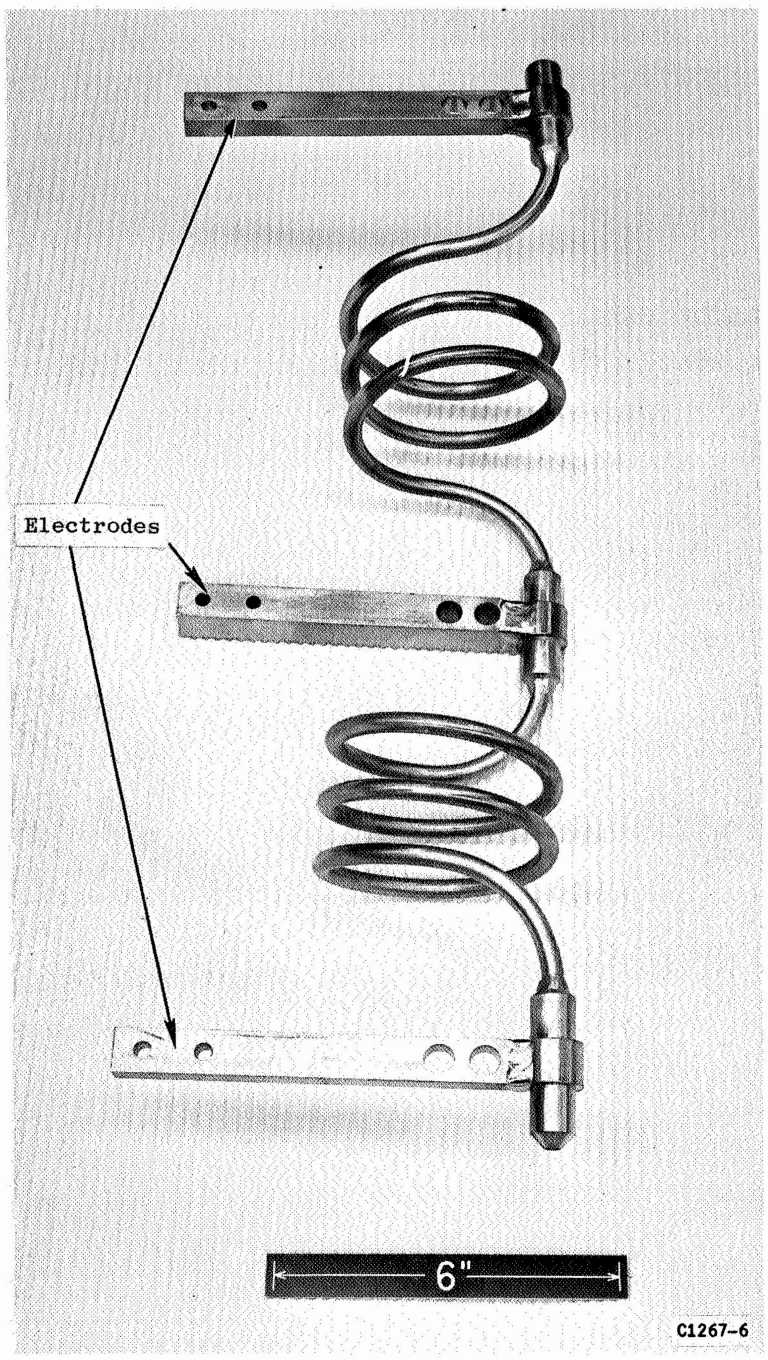

Figure 6. Potassium Preheater of Corrosion Loop I (T-111).
(Orig. C67052559)

the lithium which was inadvertently added to the still receiver during the initial fill of the still pot[2]. Two samples of distilled lithium have been obtained from the still and analyzed for oxygen, nitrogen, carbon, and metallic impurities. The analytical history of this material is presented in Tables III and IV.

The I-tubes used to determine the liquid level in the still pot functioned very well during the distillation as did the entire distillation system. The Cb-1Zr, below the bimetallic joints, at the bottom of the condenser was controlled in the temperature range of 390°F to 450°F with an air flow rate of about 200 SCFH through the condenser cooling coils.

The date in Table III shows that the carbon and calcium concentration in the lithium were reduced by filtering, and that nitrogen, carbon, and calcium concentrations were reduced by hot trapping and filtering. Neither filtering nor hot trapping had any significant effect on the concentration of oxygen. Distillation reduced the concentrations of metallic impurities but had no significant effect on nitrogen and carbon concentrations.

Oxygen analyses were performed by General Atomic, San Diego, California using fast neutron activation techniques. It was anticipated that the oxygen level would be reduced by distillation. The lithium may have been contaminated during sampling or analysis. This postulate will be checked by analyzing another sample. If similar oxygen concentration are obtained, an additional quantity of lithium will be distilled and analyzed.

C. ADVANCED TANTALUM ALLOY CAPSULE TESTS

The results of the preliminary capsule tests indicated welded ASTAR 811 and ASTAR 811CN alloys containing oxygen in concentrations in excess of 400 ppm lacked sufficient compatibility with potassium to be considered for

---

(2) Advanced Refractory Alloy Corrosion Loop Program, Quarterly Progress Report Number 8 for Period Ending April 15, 1967, NASA Contract NAS 3-6474, to be published.

TABLE III. ANALYSIS OF LITHIUM FOR OXYGEN, NITROGEN, AND CARBON

SAMPLE DESIGNATION	CHEMICAL ANALYSIS - ppm IN LITHIUM			
	O[a]	N[b]	C[c]	Ca[d]
As-Received				
Sample Number 292	130 ± 25	801	134	133
	130 ± 25	834	158	
		871		
After Filtering at 400°F through a 5-micron Filter				
Sample Number 293	150 ± 28	755	97	53
	160 ± 28	778	101	
		841		
After Hot Trapping at 1500°F for 126 Hours				
Sample Number 309	106 ± 16	11		5
	123 ± 13	10		
		5		
Sample Number 627		12	38	
		14	48	
Distilled				
Sample Number 1031	245 ± 36	19	33	
		18	42	<5
Sample Number 1064	138 ± 41	4	32	
		22	56	
			59	

(a) Fast neutron activation

(b) Micro Kjeldahl

(c) Combustion conductometric

(d) Spectrographic

TABLE IV. ANALYSIS OF LITHIUM FOR METALLIC IMPURITIES

ELEMENT	Metallic Impurities - ppm in Lithium[(a)] Sample Designation: AS RECEIVED (SAMPLE NO. 292)	FILTERED (SAMPLE NO. 293)	HOT TRAPPED (SAMPLE NO. 309)	DISTILLED (SAMPLE NO. 1031)
Ag	< 5	< 5	< 5	< 5
Al	< 5	< 5	5	< 5
B	<50	<50	<50	<50
Ba	75	50	<50	<50
Be	< 5	< 5	< 5	< 5
Ca	133	53	5	< 5
Cb	<25	<25	<25	<25
Co	< 5	< 5	< 5	< 5
Cr	< 5	< 5	< 5	< 5
Cu	< 5	< 5	28	< 5
Fe	< 5	< 5	5	< 5
Mg	5	5	< 5	< 5
Mn	< 5	< 5	< 5	< 5
Mo	< 5	< 5	< 5	< 5
Na	53	133	80	<25
Ni	< 5	< 5	28	< 5
Pb	<25	<25	<25	<25
Si	5	5	28	5
Sn	<25	<25	<25	<25
Sr	5	5	< 5	< 5
Ti	< 5	< 5	< 5	<25
V	<25	<25	< 5	<25
Zr	< 5	< 5	< 5	<25

(a) Spectrographic analysis

capsule construction. The capsule tests have been modified to include the testing of ASTAR 811C (Ta-8W-1Hf-1Re-0.012C) alloy in place of the ASTAR 811 alloy. Two potassium reflux capsules will be constructed from ASTAR 811C alloy sheet and will contain two contaminated (300 ppm oxygen) bend specimens.

One specimen will be in the as-welded condition whereas the other specimen will be welded and postweld annealed. The ASTAR 811C alloy's resistance to corrosion by potassium can, therefore, be evaluated in both the as-received condition (represented by the capsule) and oxygen contaminated condition (represented by the specimens).

A similar plan will be employed to evaluate the lithium corrosion resistance of the ASTAR 811C alloy. Two thermal convection capsules will be constructed of ASTAR 811C alloy sheet. Bend specimens of contaminated ASTAR 811C in the aforesaid conditions will be suspended in the lithium by means of hooks on the T-111 alloy downcomer tube. The design of the ASTAR 811CN mass transfer capsule and the test plans of all the capsules have not changed[3].

D. QUALITY ASSURANCE

A failure mode and effects analysis report for Corrosion Loop I (T-111) is in preparation.

---

(3) Advanced Refractory Alloy Corrosion Loop Program, Quarterly Progress Report Number 6 for Period Ending October 15, 1966, NASA Contract NAS 3-6474, NASA-CR-72177, p. 14-20.

IV. FUTURE PLANS

A. Fabrication of the Corrosion Loop I (T-111) sub-assemblies will be completed, and the sub-assemblies will be post-weld annealed at 2400°F.

B. The distilled lithium will be resampled and analyzed.

C. Specimens of oxygen contaminated ASTAR 811C alloy will be prepared and capsule fabrication will be initiated.

D. The failure mode and effects analysis report for Corrosion Loop I (T-111) will be issued.

PUBLISHED REPORTS

Quarterly Progress	For Quarter Ending
Report No. 1 (NASA-CR-54477)	July 15, 1965
Report No. 2 (NASA-CR-54845)	October 15, 1965
Report No. 3 (NASA-CR-54911)	January 15, 1966
Report No. 4 (NASA-CR-72029)	April 15, 1966
Report No. 5 (NASA-CR-72057)	July 15, 1966
Report No. 6 (NASA-CR-72177)	October 15, 1966
Report No. 7 (NASA-CR-72230)	January 15, 1967
Report No. 8 (NASA-CR-72335)	April 15, 1967
Report No. 9 (NASA-CR-72336)	July 15, 1967

DISTRIBUTION LIST
QUARTERLY AND FINAL PROGRESS REPORTS

CONTRACT NAS 3-6474

National Aeronautics and Space Administration
Washington, D.C. 20546
Attn: Arvin Smith (RNW)

National Aeronautics and Space Administration
Washington, D.C. 20546
Attn: Simon V. Manson (RNP)

National Aeronautics and Space Administration
Washington, D.C. 20546
Attn: George C. Deutsch (RR)

National Aeronautics and Space Administration
Washington, D.C. 20546
Attn: Dr. Fred Schulman (RNP)

National Aeronautics and Space Administration
Scientific & Technical Information Facility
P.O. Box 33
College Park, Maryland 20740
Attn: Acquisitions Branch (SQT-34054)
(2+repro)

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771
Attn: Librarian

National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23365
Attn: Librarian

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: Librarian, MS 60-3

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: Dr. Bernard Lubarsky (SPSD),
MS 500-201

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: G. M. Ault, MS 105-1

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: R. L. Davies (NPTB), MS 500-201 (2)

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: John E. Dilley (SPSPS), MS 500-309

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: Maxine Sabala, MS 3-19

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: T. A. Moss, MS 500-201

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: Coulson Scheuermann, MS 106-1

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: Report Control Office, MS 5-5

National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attn: V. Hlavin, MS 3-14 (Final only)

Report Distribution List - NAS3-6474 - Quarterly and Final (Continued)

National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas 77001
Attn: Librarian

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 38512
Attn: Librarian

National Aeronautics and Space Administration
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 99103
Attn: Librarian

National Aeronautics and Space Administration
Western Operations Office
150 Pico Boulevard
Santa Monica, California 90400
Attn: John Keeler

National Bureau of Standards
Washington, D.C. 20225
Attn: Librarian

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio 45433
Attn: Charles Armbruster, ASRPP-10

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio 45433
Attn: AFML (MAMP, J. K. Elbaum)

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio
Attn: AFAPL (APIP)

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio
Attn: George E. Thompson, APIP-1

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio
Attn: George Glenn

Army Ordnance Frankford Arsenal
Bridesburg Station
Philadelphia, Pennsylvania 19137
Attn: Librarian

Bureau of Mines
Albany, Oregon
Attn: Librarian

Bureau of Ships
Department of the Navy
Washington, D.C. 20225
Attn: Librarian

Bureau of Weapons
Research & Engineering
Materials Division
Washington, D.C. 20225
Attn: Librarian

U.S. Atomic Energy Commission
Technical Reports Library
Washington, D.C. 20545
Attn: J. M. O'Leary (2)

National Aeronautics and Space Administration
Washington, D.C. 20546
Attn: H. Rochen RNP

U.S. Atomic Energy Commission
Germantown, Maryland 20767
Attn: Col. Gordon Dicker,
SNAP 50/SPUR Project Office

U.S. Atomic Energy Commission
Germantown, Maryland 20767
Attn: K. E. Horton

U.S. Atomic Energy Commission
Technical Information Service Extension
P.O. Box 62
Oak Ridge, Tennessee 37831 (3)

U.S. Atomic Energy Commission
Washington, D.C. 20545
Attn: M. J. Whitman

Office of Naval Research
Power Division
Washington, D.C. 20225
Attn: Librarian

U.S. Naval Research Laboratory
Washington, D.C. 20225
Attn: Librarian

American Machine and Foundry Company
Alexandria Division
1025 North Royal Street
Alexandria, Virginia
Attn: Librarian

Aerojet-General Corporation
P.O. Box 296
Azusa, California 91702
Attn: Librarian

AiResearch Manufacturing Company
Sky Harbor Airport
402 South 36th Street
Phoenix, Arizona 85034
Attn: Librarian

AiResearch Manufacturing Company
Sky Harbor Airport
402 South 36th Street
Phoenix, Arizona 85034
Attn: E. A. Kovacevich

AiResearch Manufacturing Company
Sky Harbor Airport
402 South 36th Street
Phoenix, Arizona 85034
Attn: John Dannan

AiResearch Manufacturing Company
9851-9951 Sepulveda Boulevard
Los Angeles, California 90045
Attn: Librarian

Argonne National Laboratory
Library Services - Dept. 203CE-125
9700 South Cass Avenue
Argonne, Illinois 60439
Attn: Report Section

Atomics International
8900 DeSoto Avenue
Canoga Park, California 91303
Attn: Harry Pearlman

Avco
Research and Advanced Development Department
201 Lowell Street
Wilmington, Massachusetts 01800
Attn: Librarian

Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201
Attn: Librarian

Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201
Attn: Dr. E. M. Simmons

Battelle-Northwest Labs
P.O. Box 999
Richland, Washington 99352

The Bendix Corporation
Research Laboratories Division
Southfield, Michigan
Attn: Librarian

The Boeing Company
Seattle, Washington 98100
Attn: Librarian

Brookhaven National Laboratory
Upton Long Island, New York 11973
Attn: Librarian

Chance Vought Aircraft, Incorporated
P.O. Box 5907
Dallas, Texas 75222
Attn: Librarian

Report Distribution List - NAS3-6474 - Quarterly and Final (Continued)

Clevite Corporation
Mechanical Research Division
540 East 105th Street
Cleveland, Ohio 44108
Attn: N. C. Beerli, Project Administrator

Convair Astronautics
5001 Kerrny Villa Road
San Diego, California 92111
Attn: Librarian

Curtiss-Wright Corporation
Wright-Aeronautical Division
Wood-Ridge, New Jersey 07075
Attn: S. Lombardo

Ford Motor Company
Aeronutronics
Newport Beach, California 92660
Attn: Librarian

General Atomic
John Jay Hopkins Laboratory
P.O. Box 608
San Diego, California 92112
Attn: Librarian

General Atomic
John Jay Hopkins Laboratory
P.O. Box 608
San Diego, California 92112
Attn: Dr. Ling Yang

General Electric Company
Atomic Power Equipment Division
P.O. Box 1131
San Jose, California

General Electric Company
Missile and Space Division
P.O. Box 8555
Philadelphia, Pennsylvania 19114
Attn: Librarian

General Electric Company
Vallecitos Atomic Lab
Pleasanton, California 94566
Attn: Librarian

General Dynamics/Fort Worth
P.O. Box 748
Fort Worth, Texas 76100
Attn: Librarian

General Motors Corporation
Allison Division
Indianapolis, Indiana 46206
Attn: Librarian

Hamilton Standard
Division of United Aircraft Corporation
Windsor Locks, Connecticut
Attn: Librarian

Hughes Aircraft Company
Engineering Division
Culver City, California 90230-2
Attn: Librarian

IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616
Attn: Librarian

Lockheed Missiles and Space Division
Lockheed Aircraft Corporation
Sunnyvale, California
Attn: Librarian

Lockheed Missiles and Space Division
Lockheed Aircraft Corporation
Sunnyvale, California
Attn: John N. Cox, Staff Engineer

Marquardt Aircraft Company
P.O. Box 2013
Van Nuys, California
Attn: Librarian

The Martin Company
Baltimore, Maryland 21203
Attn: Librarian

The Martin Company
Nuclear Division
P.O. Box 5042
Baltimore, Maryland 21220
Attn: Librarian

Report Distribution List - NAS3-6474 - Quarterly and Final (Continued)

Martin Marietta Corporation
Metals Technology Laboratory
Wheeling, Illinois
Attn: Librarian

Materials Research and Development
Manlabs, Incorporated
21 Erie Street
Cambridge, Massachusetts 02139

Materials Research Corporation
Orangeburg, New York
Attn: Librarian

McDonnel Aircraft
St. Louis, Missouri 63100
Attn: Librarian

MSA Research Corporation
Callery, Pennsylvania 16024
Attn: Librarian

North American Aviation
Los Angeles Division
Los Angeles, California 90009
Attn: Librarian

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attn: W. H. Cook

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attn: W. O. Harms

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attn: Librarian

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attn: J. H. DeVan

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attn: G. Goldberg

Pratt & Whitney Aircraft
400 Main Street
East Hartford, Connecticut 16108
Attn: Librarian

Republic Aviation Corporation
Farmingdale, Long Island, New York
Attn: Librarian

Rocketdyne
Canoga Park, California 91303
Attn: Librarian

Solar
2200 Pacific Highway
San Diego, California 92112
Attn: Librarian

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78206

Superior Tube Company
Norristown, Pennsylvania
Attn: A. Bound

Sylvania Electrics Products, Incorporated
Chemical & Metallurgical
Towanda, Pennsylvania
Attn: Librarian

TRW Inc.
Caldwell Res Center
23555 Euclid Avenue
Cleveland, Ohio 44117
Attn: Librarian

Union Carbide Corporation
Stellite Division
Kokomo, Indiana
Attn: Librarian

Union Carbide Nuclear Company
P.O. Box X
Oak Ridge, Tennessee 37831
Attn: X-10 Laboratory,
Records Department (2)

Union Carbide Metals
Niagara Falls, New York 14300
Attn: Librarian

Mr. W. H. Podolny
United Aircraft Corporation
Pratt & Whitney Division
400 W. Main Street
Hartford, Connecticut 06108

United Nuclear Corporation
Research and Engineering Center
Grassland Road
Elmsford, New York 10523
Attn: Librarian

Union Carbide Corporation
Parma Research Center
P.O. Box 6115
Cleveland, Ohio 44101
Attn: Technical Information Services

Wah Chang Corporation
Albany, Oregon
Attn: Librarian

Westinghouse Electric Corporation
Astronuclear Laboratory
P.O. Box 10864
Pittsburgh, Pennsylvania 15236
Attn: Librarian

Westinghouse Electric Corporation
Astronuclear Laboratory
P.O. Box 10864
Pittsburgh, Pennsylvania 15236
Attn: R. T. Begley

Westinghouse Electric Corporation
Materials Manufacturing Division
RD #2 Box 25
Blairsville, Pennsylvania
Attn: Librarian

Westinghouse Electric Corporation
Aerospace Electrical Division
Lima, Ohio
Attn: P. E. Kueser

Westinghouse Electric Corporation
Research & Development Center
Pittsburgh, Pennsylvania 15235
Attn: Librarian

Wyman-Gordon Company
North Grafton, Massachusetts
Attn: Librarian

Grumman Aircraft
Bethpage, New York
Attn: Librarian

Lawrence Radiation Laboratory
Livermore, California
Attn: Dr. James Hadley

Lawrence Radiation Laboratory
Livermore, California
Attn: Librarian (2)

Allison-General Motors
Energy Conversion Division
Indianapolis, Indiana
Attn: Librarian

North American Aviation, Inc.
Atomics International Division
P.O. Box 309
Canoga Park, California 91304
Attn: Director, Liquid Metals Information Center

Douglas Aircraft Company, Inc.
Missile and Space Systems Division
3000 Ocean Park Boulevard
Santa Monica, California
Attn: Librarian

Climax Molybdenum Company of Michigan
1600 Huron Parkway
Ann Arbor, Michigan 48105
Attn: Librarian

Climax Molybdenum Company of Michigan
1600 Huron Parkway
Ann Arbor, Michigan 48105
Attn: Dr. M. Semchyshen

Fansteel Metallurgical Corporation
North Chicago, Illinois
Attn: Librarian

National Research Corporation
405 Industrial Place
Newton, Massachusetts
Attn: Librarian

Varian Associates
Vacuum Products Division
611 Hansen Way
Palo Alto, California
Attn: Librarian

Universal Cyclops Steel Corporation
Refractomet Division
Bridgeville, Pennsylvania
Attn: C. P. Mueller

Los Alamos Scientific Laboratory
University of California
Los Alamos, New Mexico
Attn: Librarian

Lockheed Georgia Company
Division, Lockheed Aircraft Company
Marietta, Georgia
Attn: Librarian

TRW, Inc.
TRW Systems Group
One Space Park
Redondo Beach, California 90278
Attn: Dr. H. P. Silverman

Sandia Corporation
Aerospace Nuclear Safety Division
Sandia Base
Albuquerque, New Mexico 87115
Attn: A. J. Clark

Sandia Corporation
Aerospace Nuclear Safety Division
Sandia Base
Albuquerque, New Mexico 87115
Attn: Librarian

Sandia Corporation
Aerospace Nuclear Safety Division
Sandia Base
Albuquerque, New Mexico 87115
Attn: James Jacob